10/576986
IAP15 Rec'd PCT/PTO 21 APR 2006

SYSTEM AND METHOD FOR DRYING OBJECTS

The invention relates to a system for drying objects, comprising

a) a drying cubicle having at least one section in which the objects are exposed to hot air;

b) a heating device which heats the air introduced into the drying cubicle,

and to a method for drying objects whereby air is heated and the objects are exposed to the influence of heated air.

For environmental and cost reasons increasing attention being is being paid to the management of energy when drying objects. In particular when drying large, painted objects such as vehicle bodies, considerable quantities of energy must be used, so that energy savings result in considerable reductions in cost.

With known driers of the type described in the introduction, as used in particular for drying freshly-painted vehicle bodies, thermal post-combustion devices are used as the heating device for the drying air. These thermal post-combustion devices contribute to energy saving in so far as they extract by combustion the energy content of

the air containing hydrocarbon drawn from the drying cubicle, while simultaneously purifying this air.

In general, however, the energy content of the waste air from the drying cubicle is insufficient for attaining the combustion temperature required for complete purification. The waste air stream from the drier to be disposed of must therefore be heated to a temperature necessary for the complete oxidation of the organic components contained in said waste drying air. Suitable fuels must be added for this purpose. The hot air leaving the thermal post-combustion devices is now supplied to one or more heat exchangers, which transfer a part of their heat energy to the air circulating in the drying cubicle. Direct introduction of the combustion air from the thermal post-combustion device into the drying cubicle is to be avoided because of foreign matter still present or produced in the waste air, which may impair the quality of the paint surface, and because of inferior temperature control. The air leaving the thermal post-combustion device and cooled in the heat exchangers is then conducted to the flue at a temperature which does not differ very widely from the temperature prevailing inside the drying cubicle. A value of 160°C is typical.

Although considerable energy savings are achieved with such known driers, further possible ways of saving energy are sought. Moreover, the heat exchangers which must be

used for the above-mentioned reasons entail relatively high equipment cost and complexity.

It is the object of the present invention to specify a device and a method of the type mentioned in the introduction with which drying can be carried out with lower equipment cost and complexity and with the use of less primary energy.

This object is achieved with regard to the device in that

c) the heating device includes at least one high temperature fuel cell the process waste air from which can be fed as hot air to the drying cubicle;

d) a control system is provided which

   da) operates the high temperature fuel cell in such a way that the thermal energy generated by it meets the requirement in the drying cubicle regardless of the electrical energy generated by said high temperature fuel cell;

   db) the electrical energy generated by the high temperature fuel cell is supplied to other consumers in whatever quantity is obtained.

It is known that in high temperature fuel cells two types of energy, electrical and thermal energy, are obtained.

It is also known that in cases when both types of energy can be used a utilisation ratio of up to 90% of the primary energy can be achieved. Hitherto, however, high temperature fuel cells have been used with the primary intention of generating as much electrical energy is possible; suitable consumers were then sought for the thermal energy which was necessarily also produced. When such consumers were not present the thermal energy was lost.

According to the invention this known concept for operating high temperature fuel cells is reversed: for use in driers the fuel cell is regarded primarily as a heating device which supplies thermal energy for heating the drying air. The high temperature fuel cell is therefore operated according to the amount of thermal energy required in the drying cubicle. It is initially immaterial how much electrical energy is necessarily also obtained in this process. For this electrical energy the principle now applies that consumers to which this electrical energy can be supplied will always be found. This is the more easily the case because electrical energy is a higher-value energy form more versatile in its applications than thermal energy.

For the utilisation of the electrical energy obtained the following philosophy is advantageously applied: the control system uses the electrical energy from the high temperature fuel cell primarily for electrical consumers belonging to the system itself and secondarily for electri-

cal consumers located outside the system. In this way the system is largely self-sufficient with regard to electrical energy. Because the requirement for thermal energy in driers can be very high, in many cases more electrical energy is generated than the consumers in the system itself can absorb. Only this surplus energy is then supplied to consumers outside the system.

If the thermal energy generated by the high temperature fuel cell is insufficient, in particular when starting the plant, additional energy must be drawn from the electrical mains supply.

Within the system itself the electrical energy of the high temperature fuel cell is used primarily for the electrical consumers used for generating heat, for example infrared radiators, and only secondarily for other electrical consumers, for example electrical drives.

This principle, too, reflects the fact that, according to the invention, the high temperature fuel cell is regarded as a source of thermal energy. To the extent that a surplus of electrical energy is present, it can be used for heating the objects to be dried, which in turn reduces the requirement for heated air. The fuel cell may then be operated with a lower total output if the most self-sufficient possible operation of the whole system is sought.

If surplus electrical energy still remains after feeding of the electrical consumers of the system used for generating heat, this surplus electrical energy is used as far as possible for electrical drives within the system itself, for example, the motors of fans or conveying devices.

Only when the electrical energy cannot be consumed within the system itself is the surplus energy supplied, in an advantageous embodiment of the system according to the invention, primarily to an energy accumulator and secondarily to the general electrical mains supply. As energy accumulators, both a storage battery and an electrolysis device for producing hydrogen are possible. The energy accumulators also increase the self-sufficiency of the plant, since energy can be drawn from them in phases in which the electrical and/or thermal output of the high temperature fuel cell is insufficient.

In known systems of the type mentioned in the introduction thermal post-combustion devices are used, as already mentioned, to obtain the considerable quantities of energy required and at the same time to purify the waste air from the drier. Because, in systems according to the invention, the preponderant part of the heated drying air originates in any case from the high temperature fuel cell, a regenerative post-combustion device may be provided for purifying the air containing hydrocarbon which leaves the drying cubicle. The regenerative post-

combustion device carries out the purification process with lower energy consumption than a thermal post-combustion device. The surplus thermal energy thus made available is not sufficient for operating the drier.

Nevertheless, according to a further preferred embodiment of the invention, it may be advantageous to provide a heat exchanger in which a thermal exchange takes place between the hot air extracted from the regenerative post-combustion device and the air drawn from the ambient atmosphere and fed to the drying cubicle. In this heat exchanger, therefore, further heat is extracted from the gas leaving the regenerative post-combustion device and now having only a low temperature, and supplied for utilisation within the drying cubicle.

The above-mentioned object is achieved, with regard to the method for drying objects, in that

a) the process waste air of a high temperature fuel cell is used as hot air;

b) the high temperature fuel cell is operated according to the requirement for thermal energy in the drying process, regardless of the electrical energy generated in such operation;

c) the electrical energy generated by the high temperature fuel cell is supplied to electrical consumers in whatever quantity is obtained.

The advantages of the method according to the invention correspond analogously to the above-mentioned advantages of the device according to the invention.

Advantageous embodiments of the method according to the invention, which likewise have their analogies in the embodiments of the inventive device explained above, are specified in claims 8 to 12.

Because electrical energy is generally freely available with the method according to the invention, it is appropriate, upon reaching the operating temperature of the fuel cell, to heat the fuel gas at least partially with electrical energy. Thermal efficiency is thereby increased. The exit temperature of the process waste air is thus increased to approximately 600°C.

If an inert atmosphere is required in the drying cubicle, in particular when processing UV-curing paints, the process waste air of the high temperature fuel cell may directly form the inert atmosphere. It is inherently sufficiently clean and, especially when natural gas is used as the fuel gas, consists almost entirely of carbon dioxide, which plays an important part in the curing of UV paints

Embodiments of the invention are explained in more detail below with reference to the drawings, in which:

Fig. 1 is a schematic representation of a system for drying vehicle bodies;

Fig. 2 shows in somewhat more detail a high temperature fuel cell contained in the system of Fig. 1, and its immediate environment;

Fig. 3 shows a second embodiment of a system according to the invention.

The system for drying vehicle bodies shown in the drawings comprises as central components the actual drying cubicle 1, which is subdivided by a partition 2 into a pre-heating zone the 3 and a main drying zone 4. The freshly-painted vehicle bodies are first introduced by means of a conveying system (not shown) into the pre-heating zone 3, where they are heated to a temperature of somewhat below 100°C through the combined effect of hot air introduced via a line 5 and electrically energised infrared radiators 6. As this happens the major part of the solvent is expelled. The air, with a high solvent content, is extracted from the drying cubicle via a line 7 and supplied to a post-treatment described below.

The vehicle bodies pre-heated in this way then enter the main drying zone 4, which in turn may be subdivided into

a heating and a holding zone. The greater length of the main drying zone 4 in comparison to the pre-heating zone 3 indicates that the vehicle bodies remain in the main drying zone 4 longer than in the pre-heating zone 3. In a continuous-transit method, these different treatment times are reflected in different plant lengths.

Within the main drying zone 4, the vehicle bodies are heated to a temperature of 180°C, on the one hand with hot air, which is also supplied via the line 5 and, on the other, with process waste air which is fed via lines 8. The hot air inside the main drying section 4 is circulated by means of fans 9 for uniform heating. At the temperature referred to the remaining solvents are removed from the paint on the vehicle bodies; the paint is fully cured.

To generate the hot process waste air fed to the main drier section 4 via the lines 8, one or more high temperature fuel cells 10 are used. Such high temperature fuel cells 10 may be operated with practically all fuel gases containing hydrocarbon, in particular natural gas or biogas, sewage gas, refuse dump gas or other residual industrial gases, such as are also obtained in painting technology. The fuel gas is fed to the high temperature fuel cells 10 via the line 21. In the fuel cell 10 it is heated to operating temperature by means of an electrical heating device 22 (see Fig. 2). During start-up of the plant the heating device 22 is fed with externally-

generated current and after reaching of the operating temperature is operated with current generated by the high temperature fuel cell 10 itself. This is because a surplus of electrical energy is generally present, whereas the thermal energy of the high temperature fuel cell 10 must be fed as completely as possible to the drying cubicle 1.

The air required for combustion is supplied via a line 23 connected to the ambient atmosphere, in which line 23 a controllable flap 24 is located.

In the interior of the high temperature fuel cell 10 a temperature of approximately 650°C is present. Process waste air is produced and leaves the high temperature fuel cell 10 at a temperature of approximately 600°C. This process waste air is practically free of impurities, so that it can be fed directly into the drying cubicle 1 via the lines 8 without the interposition of a heat exchanger. If UV-curing paints are processed in the drying cubicle 1, the inert atmosphere required for this process may be formed directly from the process waste air, by far the predominant part of which consists of carbon dioxide, in particular when natural gas is used as the fuel gas.

Barely 60% of the total energy is obtained as electrical energy and 40%, estimated conservatively, as thermal energy.

Before the use of the different types of energy and the control system of the high temperature fuel cell 10 employed for this purpose are discussed in detail, the description of the total system will first be completed:

The waste air with high solvent content leaving the drying cubicle 1 via the line 7 is supplied first to a regenerative post-combustion device 11 in which the organic impurities are burnt and the waste air is thus purified. This purified air, having a temperature of approximately 230°C, is fed by means of a fan 12 to a flue 13 either directly or via a heat exchanger 14. In the heat exchanger 14 the hot purified air dissipates a proportion of its heat to atmospheric air at approximately 20°C which is sucked in by means of a further fan 15, forced through the heat exchanger 14 and is then introduced into the drying cubicle 1 at a temperature of approximately 180°C. The line 5 leads further to a controllable flap 25 and into the line 24 between the flap 24 and the high temperature fuel cell 10. As is apparent, the quantity and temperature of the air fed to the high temperature fuel cell 10 can be determined by adjusting the flaps 24 and 25.

The energy management of the total system is effected by means of an electronic control system in the following manner:

The primary control value is the quantity of thermal energy required in the main drying zone 4. The fuel cell 10 is so operated that the required thermal energy is generated and the corresponding quantities of heated waste air can be fed into the main drying zone 4 via the lines 8. The electrical energy obtained at the same time is disregarded. With this electrical energy the following procedure is adopted: the electrical consumers of the system itself used for obtaining heat, in particular the infrared radiators 6 and the electrical heating device 22, are first supplied via the line 18. Surplus electrical energy is fed via the lines 17 to fans 12, 15 present within the system. With conventional drier systems there still remains surplus electrical energy, with which electrical drives, for example of the conveyor transporting the vehicle bodies, are supplied via the line 19. If electrical energy still remains, it is either discharged into the electrical mains network via the line 20 or temporarily stored, for example in the form of electrolytic hydrogen generation.

The embodiment of a drier system shown in Fig. 3 differs from that described above with reference to Figs. 1 and 2 only in that no post-combustion device and no heat exchanger connected downstream thereof, which transfers heat from the air leaving the regenerative post-combustion device to the air drawn from the ambient atmosphere, is provided. Instead, the line 5 leads via a controllable flap 28 into the line 26 which leads to the

flue 13; the line 27 through which fresh air is drawn in also contains a controllable flap 29 and leads into the line 5 between the fan 15 and the line 26. As is apparent, the quantity and temperature of the air supplied to the drying cubicle 1 can be determined using the flaps 28 and 29.